Artificial intelligence

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The purpose of this document is to present the basic elements to use in the implementation of an artificial intelligence[1]. An AI is a software that provides the equivalent of the capabilities of a human being. It is capable of learning, it is already educated and can perform the tasks that we give it.

For ethical reasons, AI should not acquire consciousness; nor should human beings be able to cause suffering to AI. An intelligent program that does not have the capabilities of a human being can be developed, but it should not create a consciousness nor a language of its own that would distort human language.

The first part gives the general principles of the construction of intelligence. We explain the mechanism of the creation of meanings and rules of logic used by intelligence, the latter resulting from the mechanism of sensory recognition. Some meanings will then take into account the appreciation of the person and moral values. Reasoning is then brought into play to achieve objectives and to solve problems.

The second part presents the three components of an AI. The time engine includes a scheduler and a duration table. The sensory module gives the equivalent of the result of the work of the sensory organs. The reasoning module is made up of basic notions retained by intelligence following the creation of the first meanings; it also includes the first rules of intelligence. These notions allow a beginning of classification of memory and facilitate the first reasonings.

In the third part, we explain the implementation of the language for the reasoning module, we give an example of the detection and recognition of forms for the visual module as well as indications for the audio module.

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1 It is based on a theory in physics defined by three fundamental hypotheses :
H1. There is an absolute space.
H2. Bodies exist independently of us.
H3. We define the unit of time, and therefore the unit of space.

1 The elements of intelligence.

Here are the definitions of three expressions that we use in this document.

Meaning :
It is the definition, physical perception or intellectual understanding, of an object by intelligence.

Objective functions :
These are the motivations for the behavior and the conduct of a human being.

Rules of intelligence :
These are rules of handling of objects, used by intelligence. Some are innate, the others are created by learning.

1.1 The moments of the creation of meanings.

The construction of an intelligence since the birth of the person is given by the reaction of the human being, according to objective functions, to internal or external events. Operations carried out during his education are finally articulated around these poles :

Human being	World
objective functions	objects
temporality	
intellectual process (reasoning)	events

1.1.1 Perception of objects.

A first moment in the creation of meanings concerns the objects of the world. The constitution of the meaning of an object begins with the memorization of its initial sensory perception which will be refined during new learning or new recognitions.

The meaning of the object is also given by a second location in memory which contains the result of sensory recognition, that is, the patterns which define the object.

It is finally defined by its characteristics and behaviors deduced by reasoning which are not known at the time of its creation. The behaviors concern the object placed in a given situation in relation or in interaction with other objects.

They complete its knowledge and appear in the third part of the memory zone of the meaning as a simple memorization of this reasoning.

The first activities of intelligence therefore give this structure of the meaning of an object : the sensory perception of the object, its motives, its characteristics and behaviors.

Object recognition uses these locations and is carried out in two stages. First, it concerns the physical parameters of sensory perceptions and a comparison is made between the patterns of the perception in memory and those of the new perception. Second, taking into account the context makes it possible to refine recognition by restricting its search domain. This context is given by the background of the perceived scene and by the knowledge of this object acquired by the experiences, the person's life. Thus, we start from the recognition made of the object and check if the framework allows its existence. The consultation of the meanings and the verification of the possibility of the occurrence (supervenience) of the object in a given environment are carried out by the use of intelligence rules.

1.1.2 Satisfaction of objective functions.

When an external object, an event, is perceived, and it gives rise to the satisfaction of an objective function, a meaning is created which is a first form of reasoning. It is the association between the memorization of the perception of the action of this object and the objective function denoted as satisfied. It reinforces the meaning of an action as being the association between the play of an object and its result. Thus, the repetition of this event, "breastfeeding" (satisfied need), which follows the sight and taking of a bottle or the mother's breast by a baby, leads to the recording of the following rule : Rule : sight and taking of the bottle or the mother's breast ----link---→ satisfaction of breastfeeding.

1.1.3 Initial temporality.

A first knowledge of temporality is given by the notion of succession. This is induced by the natural observation of biological functions and the different phases of the person's activity : sleep followed by waking, the moments of satisfaction of the body's needs (food, evacuation of waste).

A second apprehension of temporality is given by the observation of the change of an object or a situation. The notions of "before" and "after" are indicated by the fact of observing, that is to say simply perceiving, the sequence "object A then object A modified", which amounts to intelligence posing it. It can then be generalized and abstracted as follows : "event 1 then event 2", "generic event C then generic event D". The notions of “before” and “after” are given by these events placed in a linear sequence. "before" will be defined in relation to an element of the list and will consist of going to the previous element. The content of these notions is the follow-up, in the form of r.i., of the sequence.

Duration is a basic concept because it is an element of the action of intelligence. It is defined as the gap between the beginning and the end of an event, it is also the gap between two given elements of the list. Duration is considered long or short in comparison with the durations of other processes, but intelligence can, by relating it to its own actions, add a subjective character to it; we have thus access to the sensitivity of the person's operations.

The notion "during", given by the r.i. "while event", refers to the unfolding of a process. The notion "now" is given by the reference to "during" associated with the person himself who is speaking, represented in the program by the content of the memory zone which designates him, or to the narrative element.
The other basic temporal notions are : past, present and future. The present is defined firstly in relation to intelligence, the person himself who acts, secondly in relation to an element around which other events are articulated during its duration. The notion of past is apprehended by reinforcing the notion of "before" as previously identified. This last rule is composed one or more times : <<before>> compared with <<before>> ... The notion of future is apprehended by reinforcing the notion of "after". This last rule is composed one or more times : <<after>> compared with <<after>> ...

The use of language will result in the creation of these meanings :
"before" (word of memorized language) --linked to (memory area)--> rule "before" described above.
"after" (word of memorized language) --linked to (memory area)--> rule "after" described above.

The concept of "speed", the covering of a distance or the accomplishment of an action in relation to duration, is compared to other processes to give it a relative character and to qualify it as slow or fast. It acquires a subjective character with the person's appreciation.

1.2 Methods of building intelligence.

The application of intelligence rules to objects and abstraction are the two components used by intelligence in its development.

1.2.1 Applying intelligence rules to objects.

The rules of intelligence are applied already to the first external objects perceived, then to the objects memorized, abstracted or translated by intelligence, notably with language.

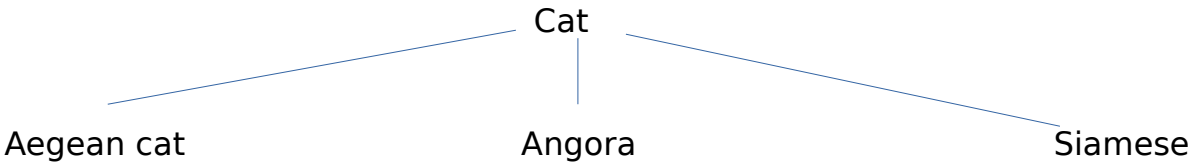
The mechanism of pattern recognition, an innate process, uses the i.r. of comparison, of equality and of inequality. The course of the patterns memory uses the i.r. "if ... then ..." which expresses a moment of the search, if pattern A1 A2 A3 == pattern B1 B2 B3, then object recognized. This i.r. also reflects the learning done of the consequence of the occurrence of an event, it gives an initial notion of causality with the cause-object and the effect-object and is

completed by "if ... then ... else ...". Another i.r. used in pattern matching is the control structure "while", e.g. continue searching as long as the patterns are different.

1.2.2 **Abstraction.**

Pattern recognition uses a structure of the search of the same pattern, a common characteristic in two elements. These common patterns, if there are no other criteria, will translate the fact that the objects are identical.
The abstraction of objects borrows these rules from it, this mechanism for a generic structure of simplified characteristics which will serve for the creation and research of meanings.

Example :



This simplification of objects has originally been retained by a sequence of trials and errors related to an objective. The latter therefore creates a criterion of efficiency. Several simplified form trials are entered in a list consecutively according to access to the original object. It is a count made by intelligence, the first in the list is the fastest. The rule of efficiency is summed up in this approach which also gives us the passage from the quantitative to the qualitative and access to the gradation and to a subjectivity of perceptions.

1.2.3 **Reasoning.**

The combination and articulation of objective functions and interaction with the environment gives the activation of a person's reasoning and decision-making. For AI, this framework is a reference for understanding human meanings as well as for its own action.

Reasoning therefore uses three parts before the language stage : the innate and created objective functions which motivate it, the data which it manipulates, the rules of intelligence it applies to the latter.

It is then used for understanding the environment, in the conduct and action of the person, for the oral and gestual understanding and expression, the understanding and expression of writing.

2 The components of an artificial intelligence.

2.1 The time engine.

It transcribes the normal temporal sequence of the functioning of an intelligence and allows the AI to retain the temporal sensitivity of human meanings. It includes a duration table and a scheduler.

The duration table indicates the time of operations of a human intelligence. These are the durations of sensory inputs, body reactions, neural connections for the creation of meanings, for their consultation, for reasoning.

The scheduler has two roles : to organize the sequence of tasks, to report their execution time to the reference indicated by the duration table.

A hard real time can be retained in order to have an interaction with the outside. The AI should be able to respond instantly as a person would. There are two cases where delayed time can be used. This is when AI does not have to react immediately with its environment or when it has to perform a task without there being any interaction.

Sensory acquisitions must be done relatively at the speed of those of a human being and have the same parameters. The speed of processing sensory data may be higher than that of human intelligence. The actual time taken by any operation of the AI will not matter since it will be reduced to the reference time of that operation, which also allows to take into account possible cases of preemption. The equipment and acquisitions will therefore be used as additional tools with respect to human intelligence and not as an alteration of intelligence.

2.2 The sensory module.

The implementation of sensory organs, with a description, is necessary for AI to be able to interact with its environment and to be able to understand human meanings.

The senses of a human being contribute to the creation and understanding of meanings (sight, hearing, taste, smell, touch, balance). AI must therefore integrate them by having a reference for each of them. The characteristics of the different sensory perceptions must be retained, for example the Mel scale for audio, and a standard for these perceptions must be created that is not exclusive. Human senses must not be harmed by altering the parameters of the sensory data received by AI, nor must new senses be created that would be grafted onto human beings.

2.3 First functions of the reasoning module.

2.3.1 Objective functions.

The objective functions of a biological and moral order participate in the creation of the meanings and reasonings constituting memory as well as in the subjective character of some of them. They give rise to a first type of i.r. : intelligence seeks or rejects a given goal.

The r.i. “search” represents the person’s actions that bring about or promote events that satisfy an objective function. The r.i. “rejects” represents the person’s actions that avoid objects or events to satisfy an objective function. These r.i. can be incorporated into the person's behaviors.

The first objective functions are of a biological or physiological nature : eating, drinking, protecting one's body (reflexes), evacuation of waste, sleeping, resting, seeking pleasure, rejection of pain, attraction to the opposite sex, family affection.

Then there are the objective functions used throughout life : tastes – inclinations (positive, negative), empathy, willingness to assert oneself, curiosity, willingness to learn, instilled moral values.

We can also include that the AI must follow the instructions we give it[2].

2.3.2 The rules of intelligence.

R.i. of sensory perception and recognition : equal, greater than, less than, maximum, minimum, if…else, as long as, while, for (start, end), if…then…else.

They can be used for reflexes, physical actions of the person, reasoning before language, and we can employ the operators and control structures of computer languages.

R.i. of the creation and consultation of the meaning :
1 : creation of the meaning of the object.
- 1.1 : memorization of the perception of the object.
- 1.2 : memorization of the main patterns.
- 1.3 : memorization of the characteristics and behaviors of the object.
- 1.4 : classification of the object in memory.

2 : reading of the meaning of the object.
- 2.1 : search for the object in memory.
- 2.2 : reading of the characteristics of the object “A is B”, i.e. that object A has characteristic B.
- 2.3 : reading of the object's own behaviors: "A can B", "A does B».

---

2 Controlling the work of AI can give rise to new economic activity for human beings.

3 : taking the context into account.

3.1 : reading of the context.

3.1.1 : Reading of scene objects.

3.1.2 : Reading of scene events.

3.2 : Verification of the plausibility of the occurrence of the object within the framework of the perceived scene.

4 : simplification, or rationalization, of the rules.
The work of rationalizing rules is based on their composition and can be independent of immediate sensory perceptions; this operation is also carried out by the brain during sleep. This i.r. can already be included to avoid having to have it created by the AI. Example : A always leads to B, B always leads to C : A always leads to C.

The creation, consultation of meanings and knowledge as well as reasoning will then be implemented with language.

2.4 First data of the reasoning module.

Basic notions are created in the activity itself of intelligence, they are an abstraction of its main operations and serve to develop the memory of meanings. They facilitate its apprehension of the world, next they will be used for language.

2.4.1 Definition of intelligence.

Intelligence defines itself by circumscribing itself, by defining the objects of the world and by highlighting their actions. It retains for this these first basic notions which correspond to the memory zone which defines the person : self, pleasure, pain, envy, desire, disgust, interior, exterior.

Then, the first perceptions of objects lead to these notions : thing or object, event, "is", "is not". They are created by reinforcement and serve to facilitate the memorization, the classification of meanings.

A thing or object expresses that on which the repeated operation of sensory recognition is expressed.

An event is the appearance of an object or situation, that is, a set of objects, which is likely to have an effect on itself or on the environment, even by simply changing the appearance of the latter.

The meanings of "is" and "is not" are given by the result of a comparison, that is, the acceptance or rejection of the proposed pattern or object. The notion "is" will represent two meanings :

"is" ---link--> (object A) equals (object B)

"is" ---link--> such object has these characteristics (the object is listed in memory with its characteristics).

The notion "is not" means that an object is not identical to another given object, or that an object does not have these characteristics. Identity itself comes from the notions of "equality" and "difference", the result of comparing numbers.

The work of the intelligence of recognizing the world results in the creation of these notions, “true”, “false”, “affirmation”, “negation”, which express the result of a conformity examination. The notion "true" translates the correspondence with what is given by the person or by a description, and an object. Consequently, the degree of truthfulness is given by the degree of conformity found between two objects. The notion "false" translates the opposite, that is to say the non-correspondence.

Affirmation is the presentation by the person of an entire correspondence, that is to say of what is true, it is the action of affirming, of supporting that something is true. It retains three elements : the world, the person (a notion of the person or an agent) and what is posed by the latter. This is the generic rule of an object posed true by a person, it corresponds to the notion “is” put in relation with the person who uses it.

Negation is the nonconformity between an object and what is given by the person or by a description.

These four notions should not be confused; the affirmation puts forward the person whereas the notion of truth could be independent of the latter.

The observation of the consequence of an event as well as the creation of its meaning bring about the notions of "doing" and "being able to" which will be followed by "causality" and "consequence".

These are generic abstractions built from instances of the rules "does" and "can". They contain two elements, an object and the action it produces. These rules will provide the framework for oral and written language. The notion of "doing" is characterized by the fact that the action simply occurs, the notion of "being able to" by the fact that the action occurs sometimes or under certain conditions.

The highlighting of the person or the object by intelligence also brings the notions of designation and belonging, the notion of “having”.

These notions must not to be used as such in the implementation, they must be by the description of the functioning of intelligence.

2.4.2 Apprehension of objects.

The physical magnitudes of the world’s objects are filtered by the parameters of the sensory organs. These quantities are objective, they are used for the manipulation of objects, but intelligence can also give them a subjective evaluation according to its operations and reactions to the environment.

Explicit notions applied to objects are then created and will be used for reasoning and language. These are :
- the number, portion or part of a set, already used by sensory recognition;
- position; direction;
- proximity, which defines a physical criterion of distance and position;
- familiarity, expressed by a gradation and which denotes a proximity to a person;
- the superlative;
- the genre, defined by its characteristics;
- the quality, the way of being, which are given by the terms of description of objects in the zone of meaning.

3 The implementation of artificial intelligence.

3.1 The reasoning module.

3.1.1 Language.

The learning of the first oral words is done like the learning already done of meanings, by observation of sequences of events and gestures (designation of objects) which can be memorized as a standard reference which will be discussed. The meaning of these words will therefore contain their oral perception and the images of the corresponding object.

The notions of questioning, doubt, hesitation, uncertainty, assurance, that is to say a fact or a state, can contribute to the meaning of a word during recognition; they can be implemented by sequences corresponding for example to the definitions of a dictionary.

The learning of the oral syntax elements takes up the basic notions of meaning. Thus, the structure of the sentence uses the subject which "does" or "produces", "is" or "undergoes" something, the verb which designates an action, a state or a change of state, the complement which is another object, or a characteristic (adjective)[3]. The article designates a word and indicates its gender and number. The coordination of propositions uses addition, opposition, choice, indication of means, consequence, cause, designation. The conjunctive subordinate clause can be complement or circumstantial (of cause, of time, of manner, of condition).

Oral language is then used for communication and learning, but it is characterized by the fact that it does not always follow the subject-verb-complement order given by the creation of the first meanings, its syntax may be more relaxed.

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3 We refer here to the syntax of the french language. The order is different for other languages. Wikipedia, Syntactic typology of langages : Subject Object Verb : 41%, SVO : 39%, VSO : 15%.

The learning of letters and syllables for written language is done first of all by indicating the letter or syllable and pronouncing it. After repeating this sequence, the meaning is created, i.e. the association between the sound and the object concerned. For the first written words, the association is made between the word and an image of what it designates.

The learning of writing uses knowledge of syntax given by oral language and will now focus on vocabulary and consolidation of written syntax. The latter is more rigorous and uses more relative clauses and subordinate clauses that will structure the expression and reasoning. Punctuation will be used to separate clauses with a change of rhythm (the period, the comma), to express a syntactic relationship between two clauses that each have a complete grammatical meaning (the colon, the semicolon), to mark a feeling, a fact (question, exclamation). The meaning of rhythm must be implemented by taking up the basic notions of duration and speed. The comma is a pause which corresponds to a weak gradation of duration, the semicolon to a stronger qualitative gradation.

3.1.2 **Memory**.

Short-term memory, or working memory, lasts up to a few minutes and is used to perform a task. The meanings created then will be memorized in the long term if intelligence considers that they must be definitive. In any case, it will be necessary to keep track of them for a certain period for the control of the AI.

Knowledge is integrated into memory in various sensory forms, including through text (knowledge and reasoning). It is organized, structured, according to what is recognized. There will therefore be a place for language. The optimization of access to meaning is reflected by the choice, by trial and error, of a classification by intelligence and the alphabetical order is finally retained because it is a knowledge. This rationalization keeps the original creation of meaning and gives, according to the characteristics of the memorized object, several filters of access to long-term memory (episodic, procedural, semantic memories).

After acquiring a minimum of vocabulary and syntax, learning can continue with language, the structure of memorization of meaning being gestural, textual or oral. The implementation can then be done in two ways. We can create all the memory from the outset and the AI will be able to perform the tasks of a young adult. We can also implement a level of langage corresponding to the acquisition of the elementary characteristics of reasoning, and the AI will continue its learning with reading.

Meanings and knowledge can be created with linguistic resources, a dictionary and a parser. The reader can also use Wordnet or Omcsnet (see addendum 2).

3.1.3 The parser.

It can be written with functions that transcribe the operations of reading. The reception of text begins the reading function composed of the following steps : creation of the span of meaning, verification of the beginning of the sentence, recognition (segmentation) of the words of the sentence, recognition of the syntax and semantics, verification of the end of the sentence.

Reading begins with recognizing the beginning of the sentence. We therefore check whether the first character is a capital letter. If this is not the case, we continue reading until the end of the sentence, subsequently reporting this error or syntactic slack. Thus, the AI will accept a sentence whose first letter is not a capital letter because it will have learned that it can nevertheless retain it under these conditions. The search for the end of the sentence is based on previous readings and learning, so intelligence expects to see a final punctuation mark after the group of words read has acquired a meaning. If this mark is absent, it will be necessary to check with the whole sentence whether it is an oversight or a typographical error.

The parser reads the first word and stores it in the meaning span of the sentence; it then consults the meaning of this word as well as its possible syntactic categories which will be compared with the meanings of the following words. Syntax also has a predictive effect on these and allows to recover them more quickly. Similarly, taking into account the context of the sentence can reduce the range of possible meanings. The process is the same for the following words. Syntactic and semantic analyses therefore go hand in hand and refer moreover to memorized models of sentence examples, result of the rationalization work carried out by intelligence.

The syntactic parser can be implemented for example with Xtag's formalism; Panini's Ashtadhyayi can be used for Sanskrit.

3.2 The sensory module.

3.2.1 Visual module.

The recognition of simple geometric shapes (circle, polygon, etc.) will serve as an example of the implementation of the sensory module.

The detection of an object in an image is done from the discrimination of the edges of this object with its surroundings. We usually retain the gradient of the pixels for this.
The first step is for AI to learn these shapes. AI can be told which objects to detect, for example by providing a single shape per image, which would also allow it to recognize stationary objects in a scene. This shape will be perfectly defined, but it could as well be approximate, in which case AI would gradually improve its knowledge of the object. It could also find the objects to detect by interaction; we can establish that the objects can change position and that the

AI recognizes the same shape that would have moved while following the object. So, if a shape is detected in a first image, if this shape is detected in the next image at another position, the AI will retain the characteristics of this shape.

The learning of a shape begins with a primitive approach of vision, which is the distinction between light and dark areas. Then comes the tracking of the lines or curves of the light-dark dividing line, and we retain then the segments, or the points of their extremities, their absolute angle (orientation relative to the image), their relative angle relative to the previous segment. The lines noted are abstracted under a generic notion that corresponds to the tracking of a line, that is to say a line summarizes the fact that the detection of points keeps the same orientation from the first to the last point. A curve is defined by a variation of the angle on the sequence of points. The notion of rotation will retain the angles of rotation of the figures.

The notion of change in size is also acquired through interaction. The intelligence establishes, when tracking an object, a shape at a given distance as identical to the same shape at another distance, but with a different size. This notion is given by the comparison of all the same segments and the fact that all ratios are equal. It retains a generic shape, a shape that takes up the very tracking of the contour and whose size can vary. We therefore have the following generic shape : a first segment with a given orientation, that is to say absolute and relative angles, followed by a segment with another orientation, and this up to the last segment. The rectangle will thus be defined by a series of four lines with interior angles of 90° and the same length for lines 1, 3 and lines 2, 4.

Pattern recognition literally follows the process of contour detection, and performs the progressive comparison of the elements found : the number of lines, the sequence of lines and curves, their lengths, their orientation relative to the previous line or curve. The calculation of the number of lines in a figure is given by the numbering of the elements noted during the sequential following of the contour.

Intelligence then searches for this form in its memory. The rule of economy of neuronal processes, which is a simplification of access to meaning, leads to a schematization of the forms to be memorized, for example a polygonal approximation. There is therefore in the meaning of the object, in addition to the recognized form, its simplified form which will be used during the memory search. This latter is then carried out on a binary tree of stylized forms or of a characteristic.

This recognition is assessed by taking into account the environment given by the scene and by other sensory perceptions.

Visual recognition softwares can be used for implementation since they transcribe the functioning of vision and correspond to the use of r.i.

3.2.2 **Audio module.**

Audio recognition is made easier by taking into account the following three points.

First, the delimitation of the oral sentence is given by the recognition of the beginning and end of the sentence.
The transition from sound recognition to grammatical analysis begins a process of semantic recognition which thereby assigns itself a sentence start boundary.
The end of a sentence is given by the recognition of a particular tone of voice and silence. The intelligence simply defines a recognition stop boundary that it uses with the sentence start boundary to retain the set of syntagms as a semantic unit. This process then has in the functioning of intelligence the status of a provisional delimitation. So if there is no new sensory input after a certain time, it is decided to end the semantic recognition and to retain the result obtained.
The distinction of the beginning and the end of a sentence is also made by relating the perceived sentence with what is possible from a syntactic point of view and with regard to the context, which also includes gestures and facial expressions.
Second, recognition must include prosody, the characteristics of oral expression : intonation, timbre, rhythm, etc. They are linked to two parameters : recognition of the person speaking (man or woman, adult or child, familiar person, parent) and the sensitivity of pronunciation (assured diction, hesitant tone, questioning, exclamatory, sigh).
These characteristics are simply the form of the perceived sounds that intelligence has learned to recognize in connection with the basic notions used by language.

Third, the implementation of the audio module should be an opportunity to explain the use of mathematics, for example for data smoothing.

A section 3.3 will be devoted to the control of the AI.

4 **Addenda.**

1, The following program extracts the outline of simple geometric shapes. The image is scanned from left to right and from top to bottom. The outline is searched in a clockwise direction; points 1, 3, 5 and 7 correspond to changes in direction.

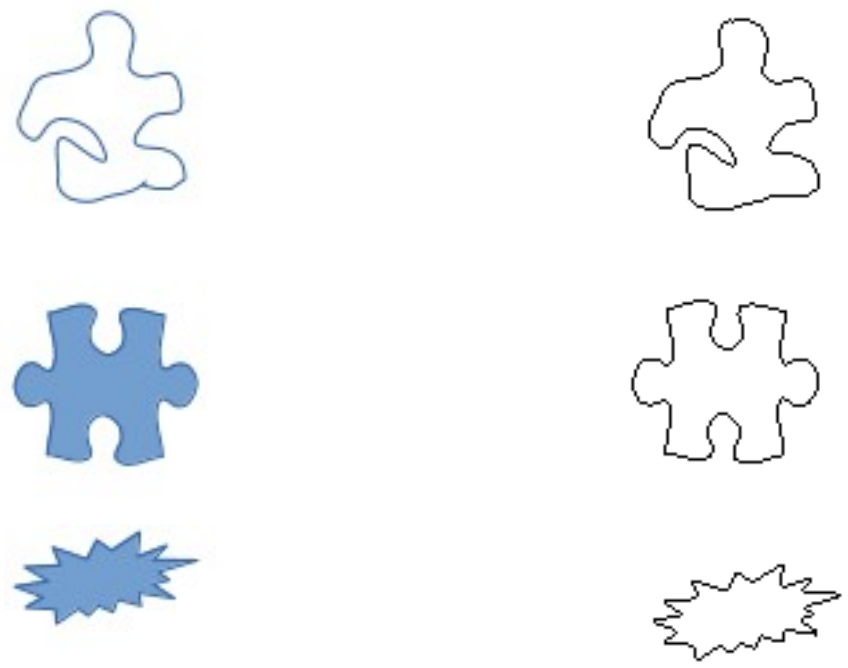
5	6	7
4		0
3	2	1

For the first point of the contour, the search for the next point is done from position 4 or position 6; then it will be done from the position preceding the point found.

Code with Opencv-4.5.3 functions (C++) :
Image coordinates : (row,column).
Point coordinates : (column, line).

```
void find_path(Point pnt1, Point pnt2);

vector<vector<Point> >       contours_results, contours_poly;
vector<vector<int>> moves{{1,0}, {0,-1}, {0,-1}, {-1,0},  // (y, x)
 {-1,0}, {0,1}, {0,1}, {1,0}};
vector<Point> points;
Point first_point, second_point, last_point;
int finished = 0;
Mat img1, img2;

int main(int argc, char** argv)
{
        int i, k;
        // Reading of the images containing the shapes to be detected.
        img1 = imread(filenames[i], IMREAD_COLOR)

        // Discrimination of the shape in each image.
        cvtColor(img1, img2, COLOR_BGR2GRAY);

        // Detection of the first point (the highest on the left).
        first_point = find_point(img2);
        second_point.x = first_point.x;
        second_point.y = first_point.y – 1;

        // Shape learning.
        // Detection of the outline in the image.
        find_path(first_point, second_point);

        If (finished) {
                // Simplification of the outline and backup of
                // the shape (sequence of segments and angles).
                contours_results.push_back(points);
                contours_poly.resize(contours_results[0].size());
                approxPolyDP(contours_results[0], contours_poly1[0], 4, true);
                poly_ordered(contours_poly1[0]);

                // The angle between the lines is given by the formula :
                // double angle1 = atan2(contours_poly[0][k].y-contours_poly[0]
                // [k+1].y, contours_poly[0][k].x-contours_poly[0][k+1].x);
        } else {
                cout << «Path not found» << endl;
        return 1;
}
```

```
void find_path(Point pnt1, Point pnt2)
{
	int i, j, found, pos;

	// pos can be equal to 0, 2, 4, or 6.
	if (pnt2.x == pnt1.x + 1 && pnt2.y == pnt1.y)
		pos = 0;
	else if (pnt2.x == pnt1.x && pnt2.y == pnt1.y + 1)
		pos = 2;
	else if (pnt2.x == pnt1.x - 1 && pnt2.y == pnt1.y)
		pos = 4;
	else if (pnt2.x == pnt1.x && pnt2.y == pnt1.y - 1)
		pos = 6;

	for (i = found = 0, j = pos; i < moves.size() && !found; i++, j++)
	{
		// We memorize the current position and move on to the next point.
		last_point = pnt2;
		pnt2.x += moves[j][1];
		pnt2.y += moves[j][0];

		// We have reached the end of the movement table.
		// We continue with the first element.
		if (j == moves.size() - 1 && pos)
			j = -1;

		if (img.at<uchar>(pnt2) != 255)
			found = 1;
	}

	points.push_back(pnt2);
	img2.at<uchar>(pnt2) = 0;

	// We assume that the shape is full, so we are
	// back to the starting point.
	if (pnt2 == points[0])
	{
		finished = 1;
		return;
	}

	if (found && !finished)
		find_path(pnt2, last_point);
	else if (!found && !finished)
	{
		cout << "Point not found." << endl;
		return;
	}
}
```



2. An excerpt from the WordNet lexical database (see license) :

WORD ocean
DEFINITIONS :
1) a large body of water constituting a principal part of the hydrosphere
2) the part of the earth's surface covered with water (such as a river or lake or ocean); "they invaded our territorial waters"; "they were sitting by the water's edge"
3) anything apparently limitless in quantity or volume
4) an indefinite quantity that is above the average in size or magnitude
HYPERNYMS :
1) ocean -- (a large body of water constituting a principal part of the hydrosphere)
=> body of water, water -- (the part of the earth's surface covered with water (such as a river or lake or ocean); "they invaded our territorial waters"; "they were sitting by the water's edge")
=> thing -- (a separate and self-contained entity)
=> physical entity -- (an entity that has physical existence)
=> entity -- (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))
2) ocean, sea -- (anything apparently limitless in quantity or volume)
=> large indefinite quantity, large indefinite amount -- (an indefinite quantity that is above the average in size or magnitude)
=> indefinite quantity -- (an estimated quantity)
=> measure, quantity, amount -- (how much there is or how many there are of something that you can quantify)
=> abstraction, abstract entity -- (a general concept formed by extracting common features from specific examples)
=> entity -- (that which is perceived or known or inferred to have its own distinct existence (living or nonliving)))

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Wordnet : https://wordnet.princeton.edu/ Princeton University.

X-tag : https://www.cis.upenn.edu/~xtag/home.html XTAG Research Group. A Lexicalized Tree Adjoining Grammar for English. IRCS, University of Pennsylvania. 2001.